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Soil hydraulic properties of cropland compared with reestablished and native grassland

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Abstract

Conversion of cropland to perennial grasses will, over time, produce changes in soil hydraulic properties. The objective of this study was to characterize and compare hydraulic properties of fine-textured soils on adjacent native grassland, recently tilled cropland, and reestablished grassland in the Conservation Reserve Program (CRP) at three locations in the Southern Great Plains. A tension infiltrometer was used to measure unconfined, unsaturated infiltration over a range of supply pressure heads– (nominally, h = –150, –100, –50, and –5 mm H_2O) at the soil surface. Intact soil cores were sampled within the Ap and Bt horizons to determine bulk density and water desorption curves, $\theta(h)$, at potentials ranging from –0.15 to –100 kPa. Unsaturated hydraulic conductivity $K(h)$ over the range in supply pressure heads was estimated using Wooding's equation for steady state flow from a disc source. The van Genuchten water retention model was fitted to $\theta(h)$ data to estimate parameter values. Soils in CRP had greater surface bulk densities than their grassland and cropland counterparts. The shape of the soil water retention curve for grassland and CRP land were similar, suggesting that converted croplands had fully reconsolidated. Mean near-saturated hydraulic conductivities of cropland at h = –5 mm were not significantly different from grassland. However, at –150 mm supply pressure head, cropped soils had a mean unsaturated conductivity 2.3 and 4.1 times greater than CRP land and grassland, respectively. Sites in CRP had the lowest ($P < 0.05$) near-saturated hydraulic conductivities (h = –5 mm), which suggests that, after 10 years, grasses had not fully ameliorated changes in pore structure caused by tillage. Comparison of unsaturated conductivities for grassland and CRP land suggest that long-term structural development on native grasslands was principally confined to effective pore radii greater than 300 μm. Land use practices had a greater effect on water movement than did soil series indicating that the modifying effects of tillage, reconsolidation, and pore structure evolution on hydraulic properties are important processes governing water movement in these fine-textured soils.

Keywords: Hydraulic properties; Porosity; Hydraulic conductivity; Soil management; Tillage; Infiltrometers.

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1. Introduction

Soil hydraulic properties can have a major influence on infiltration as well as movement of soil water to the surface during evaporation. Changes in the continuity, size, and extent of pores caused by tillage will strongly influence the surface hydraulic properties of the soil. However, studies have shown that tillage effects on infiltration rates are not consistent (Ankeny et al., 1990; Logsdon et al., 1993; Jones et al., 1994). In general, increased infiltration rates resulting from tillage operations are short lived due to settlement and crust formation (Kemper, 1993; Angulo-Jaramillo et al., 1997). Wetting-drying cycles, settling, and reconsolidation of soil after tillage changes the shape of the water release curve and modifies the conductivity-water content relationship (Gantzer and Blake, 1978; Mapa et al., 1986).

Conversion of cropland to perennial grasses will also, over time, effect changes in soil hydraulic properties (Mazurak and Ramig, 1962; Kay, 1990). This results from root activity, the development of biopores, improved aggregate stability resulting from greater carbon sequestration (Unger, 2001), and enhanced wetting-drying cycles mediated by extraction of water by perennial grasses. A primary objective of the Conservation Reserve Program (CRP) was to return cropland to perennial grasses as a means to stabilize highly erodible soils. The amelioration of a consolidated soil matrix by root activity, wetting-drying cycles, and other structure forming processes will ultimately determine the degree to which CRP sites attain hydraulic properties exhibited by native grassland sites. Although infiltration rates have been measured on CRP sites in several studies (e.g., Gilley et al., 1997; Weinhold and Tanaka, 2000), a thorough characterization of the hydraulic conductivity and water retention relationships of CRP land as related to both tilled cropland and native grassland is required to assess changes in pore structure associated with long-term reconsolidation under perennial grasses.

The tension disc infiltrometer is a valuable tool to investigate the hydraulic properties of soils at or near the surface. This infiltration-based method is particularly suitable for quantifying changes in near surface hydrology resulting from soil management activities such as tillage (Angulo-Jaramillo et al., 2000). Control of the water potential at which water is supplied to the surface limits the size of pores that are actively conducting water. Measuring infiltration rates at sequentially smaller supply water potentials permits the evaluation of flow rates within several narrowly defined pore size classes and facilitates the derivation of the conductivity-potential relationship (Ankeny et al., 1991). Moreover, disc infiltrometer measurements over a range in potentials can complement water retention data by providing indirect information pertaining to pore structure.

The objective of this study was to assess differences in near saturated hydraulic conductivity, the shape of the water retention curve, and porosity among reconsolidated CRP land, native grassland, and recently tilled cropland for three soils of the Southern Great Plains.

2. Materials and methods

Unconfined infiltration experiments at selected supply pressure heads using a disc infiltrometer were conducted on adjacent cropland, grassland, and CRP land at three locations in the Southern Great Plains from 23 June to 22 September, 1999 (Table 1). The locations were situated within a 150-km east-west transect with mean annual precipitation varying from 450 to 550 mm. At each location, three replicate plots for each land use treatment were selected for detailed infiltration measurements and soil sampling. Soil textures from the surface to 0.1 m depth ranged from clay loam to silty clay loam. All soils had a silty clay to clay B horizon beginning at 0.15 to 0.2 m depth (Unger, 2001) and a calcic horizon at greater depths. The Ulysses soil had free carbonates extending into the surface horizon. Total soil organic carbon contents were related to land use and averaged 10.1, 13.1, and 22.5 g kg^{-1} for cropland, CRP land, and grassland soils, respectively. All plots within a given location were located on the same contiguous soil survey mapping unit representing a single soil series.

Within each plot, steady-state infiltration measurements were performed on two subplots over a range of ascending pressure heads, nominally –150, –100, –50, and –5 mm H_2O (–0.05, –0.5, –1.0, and –1.5 kPa), using a 0.2-m diameter disc infiltrometer described by Evett et al. (1999). All measurements on cropland were made in nonwheel-tracked interrows. The sites were prepared by removing all vegetation, residues, and any large clods (in tilled soils) that would interfere with achieving a level surface. A layer of fine sand approximately 8-mm thick was placed over the surface to fill depressions and facilitate contact between the soil and the nylon membrane of the infiltrometer. Once infiltration was initiated, water level in the infiltrometer tube was monitored with a pressure transducer and data logger. Deionized water was permitted to infiltrate for at least

Table 1
Description of study locations and land use sites. Infiltration measurements were completed in 1999.

Land use	Soil Series [a]		
	Pullman [b]	Pantex [b]	Ulysses
Lat./Long.	102°05' / 35°11'	101°27' / 35°10'	102°45' / 35°04'
Cropland	dryland winter wheat[c] and grain sorghum; sweep-tilled 6 weeks prior to measurements.	dryland winter wheat and grain sorghum; sweep-tilled 3 weeks prior to measurements.	dryland winter wheat and grain sorghum; sweep-tilled 8 weeks prior to measurements.
CRP	established in 1989; Old World bluestem	established in 1988; Old World bluestem	established in 1988; Warm season grasses.
Grassland	native grassland; lightly grazed.	native grassland invaded by rescue grass; heavily grazed.	native grassland; moderately grazed.
Cropland (no-tillage)	dryland winter wheat-grain sorghum-fallow rotation; no-tillage since 1981.		

[a] Soil series are as follows: Pullman - Fine, mixed, superactive, thermic Torrertic Paleustoll, Pantex - Fine, mixed, superactive, thermic Torrertic Paleustoll, Ulysses - Fine-silty, mixed, superactive, mesic Aridic Haplustoll.
[b] The major difference between Pantex and Pullman series is that depth to the calcic horizon in Pullman soils is less than 150 cm.
[c] Botanical names are as follows: winter wheat (*Triticum aestivum* L.), grain sorghum *(Sorghum bicolor* (L.) Moench), Old World bluestem (*Bothriochoa ischaemum* (L.) Keng), and rescue grass (*Bromus unioloides* (Wild.) H.B.K.).

1.4, 1.2, 1.0 and 0.7 h for supply pressure heads of –150, –100, –50, and –5 mm, respectively, to ensure that near steady state conditions had been reached. Additional infiltration measurements were obtained in three plots for a no-tillage field established on the Pullman soil in 1981 (Table 1).

In conjunction with each infiltration run, two sets of undisturbed soil samples (30-mm length by 54-mm diam.) were extracted at 0.5 to 0.75 m from the disc center at the 0.01 to 0.04, 0.05 to 0.08, 0.11 to 0.14, and 0.15 to 0.18 -m depth increments for bulk density and initial water content measurements. An additional set of cores were extracted below the center of the disc for the same depth increments one day after the termination of each experiment. Water retention curves were obtained for the undisturbed samples using tension (0.15 to 15 kPa) and pressure (30 to 100 kPa) extraction methods for these four depth increments.
The van Genuchten model (van Genuchten, 1980)

$$\theta(h) = \theta_r + \frac{\theta_s - \theta_r}{\left(1 + |\alpha h|^n\right)^m} \tag{1}$$

was used to describe the water characteristic curve where θ (m^3 m^{-3}) is the volumetric water content, h is the pressure head (m), θ_r and θ_s are the residual and saturated water contents (m^3 m^{-3}), respectively, $m = 1 - (1/n)$, and n and α (m^{-1}) are empirically fitted parameters. Equation (1) was fitted to the θ(h) data obtained for each plot (typically six water retention curves for the 0.01 to 0.04 and 0.05 to 0.08-m depth increments) using the RETC code of van Genuchten et al. (1991). For these nonlinear regressions, n and α were fitted, θ_s was estimated from the average measured bulk densities for each plot, and θ_r was held constant at 0.005 m^3 m^{-3}. The θ(h) data and $K(h)$ data were not simultaneously fitted because poor estimates of θ(h) near saturation and at higher potentials can result when $K(h)$ measurements are confined to the near saturated range (Schwartz and Evett, 2002).

The Wooding (1968) approximation for steady state outflow $Q(h)$ (m^3 s^{-1}) from a circular source

$$\frac{Q(h_0)}{\pi r_0^{\,2}} = K(h_0) + \frac{4}{\pi r_0} \int_{h_i}^{h_0} K(h)\, dh \tag{2}$$

was used to estimate unsaturated conductivity at each supply pressure h_0 (m). In Eq. (2), r_0 is the radius of the infiltrometer (m), $K(h)$ is the unsaturated hydraulic conductivity, and h_i is the pressure head corresponding to the initial water content. Steady state analysis of infiltration using Eq. (2) in conjunction with a power law conductivity function that *a priori* assumes log-linearity near saturation can result in poor estimates of $K(h_0)$ (e.g. Logsdon and Jaynes, 1993). We used the method of Schwartz and Evett (2002) that substitutes the van Genuchten-Mualem (VGM) conductivity function (Mualem, 1976; van Genuchten, 1980) into Eq. (2) to obtain $K(h_0)$ estimates. The VGM conductivity function is given by

$$K(\theta) = K_s S^{1/2}\left[1 - \left(1 - S^{1/m}\right)^m\right]^2 \tag{3}$$

where K_s is the saturated hydraulic conductivity (m s^{-1}) and S is the fluid saturation ratio $(\theta - \theta_r)/(\theta_s - \theta_r)$. Steady state volumetric fluxes, $Q(h_0)$, at each of the four supply pressures, h_0, were calculated using the final 300 s of outflow data. Parameters n, α, and K_s were estimated by fitting Eq. (2) to the four steady state volumetric fluxes. The fitted water retention characteristic curve and measured initial water contents were used to estimate the initial pressure head h_i. Hydraulic conductivities at the four supply pressure heads [$K(-150)$, $K(-100)$, $K(-50)$ and $K(-5)$ with supply pressure heads expressed in mm H_2O] were obtained by substituting the optimized values of n, α, and K_s into Eq. (3).

A knowledge of the pore size distribution can help conceptualize the changes in the porous medium resulting from reconsolidation and tillage. Assuming pressure head can be related to an effective pore radius, r, by the capillary equation with a negligible contact angle, the fitted water retention relationship can be transformed (Brutsaert, 1966) to obtain the effective pore size distribution.

$$f(r) = (\partial\theta/\partial h) \cdot (\partial h/\partial r) \tag{4}$$

This distribution has the property

$$\int_0^\infty f(r) = \theta_s \tag{5}$$

to permit comparisons among pore size distributions with differing total void space.

Analyses of variance for conductivity, bulk density, and retention data were performed using the mixed linear model analysis for multi-location experimental designs (Littell et al., 1996). Location and land use were designated as fixed effects and plot replicates nested within location were designated as random effects. Mean separation was evaluated using Fisher's protected least significant difference (LSD) test. For all statistical analysis, effects were declared significant at the 0.05 probability level.

3. Results and discussion

3.1 Bulk density

The bulk density of the surface 0.05-m of soil was significantly greater on CRP land than on cropland and grassland (Table 2). For the 0.05 to 0.08 -m depth increment, cropland bulk

Table 2
Mean values of soil bulk density (Mg m^{-3}) with depth by land use.

Land Use	Soil Depth Increment			
	.01-.04 m	.05-.08 m	.11-.14 m	.15-.18 m
Cropland	1.18 a	1.29 a	1.38 a	1.46 a
CRP	1.25 b	1.40 b	1.34 a	1.41 a
Grassland	1.17 a	1.36 b	1.36 a	1.40 a

Mean values in the same column with different letters are significantly ($P < 0.05$) different using Fishers protected LSD test.

densities were lowest of the three land use treatments, reflecting the loosening effect of tillage. At greater depths, significant differences in bulk density were not detected among land use treatments. Because the shallow tillage practices on cropland were restricted to the upper 10 cm and conductivities determined using tension infiltrometry reflect near-surface ($\lesssim$ 0.1 m) soil hydraulic properties, we confined our analysis of water retention data to the 0.01 to 0.04 and 0.05 to 0.08 -m depth increments.

3.2 Water retention

Mean water retention relationships for each land use treatment at each location (Fig. 1) exhibited consistent trends between cropland and CRP land. The potentials at which retained water contents of cropland exceeded those of CRP land were mainly confined within the region from saturation to –10 kPa. This suggests that tillage influenced the pore structure of these soils principally within this range in water potentials. The two-parameter fit of the van Genuchten Eq. (1) to combined water retention data of the 0.01 to 0.04 and 0.05 to 0.08 -m depth increments in each plot (typically 6 cores) resulted in fitted values of n that exhibited remarkable consistency for plots within the same location (standard error < 0.013) and fell within the expected range for clay and silty clay soils (Yates et al., 1992). However, the fitted value of α was negatively correlated ($R^2 = 0.76$) with n and varied by nearly two orders of magnitude over the narrow range of fitted values of n ($1.08 < n < 1.20$). To reduce the influence of these correlations on fitted retention curves, we fixed the value of n to the mean value obtained at each location and carried out a one-parameter fit for all of the three plots for each land use by location treatment combination. This improved the identifiability of α while not compromising the fit to measured retention.

Results of the fit of the parameters in Eq. (1) to retention data are shown in Table 3 and Fig. 1 for each land use treatment at each location. The fitted value of α was consistently greater for cultivated plots as compared to CRP land across all locations (Table 3). Evett et al. (1999) also observed significantly higher values of α for sweep-tillage cropland as compared with no-tillage, although they fitted α in a different manner than the present study. Smaller θ_s, concomitant with a smaller fitted value of α for CRP land as compared to cropland, gives rise to a water retention curve for CRP land (Fig. 2) that resembles the change due to reconsolidation of tilled cropland as illustrated by Gantzer and Blake (1978), Mapa et al. (1986), and Ahuja et al. (1998). The Ahuja et al. (1998) analyses of retention curves indicated that tillage increased the log-log slope of the Brooks and Corey (1964) equation below the air entry pressure head. In our case for the van Genuchten retention function, an increase in α also increases the slope of the retention curve but principally at small water potentials. Alternatively, decreasing the value of n in the van Genuchten retention function to simulate reconsolidation could generate curves similar to those depicted in Fig. 2. However, because n determines the slope of the retention curve principally at larger potentials and is viewed as a parameter mostly affected by soil texture (van Genuchten and Nielsen, 1985), and because tillage principally influences the pore space approximately corresponding to the 0 to –33 kPa retention range (Ahuja et al., 1998; Or et al., 2000), a reduction in α rather than n may better represent the processes of reconsolidation after tillage for these fine-textured soils.

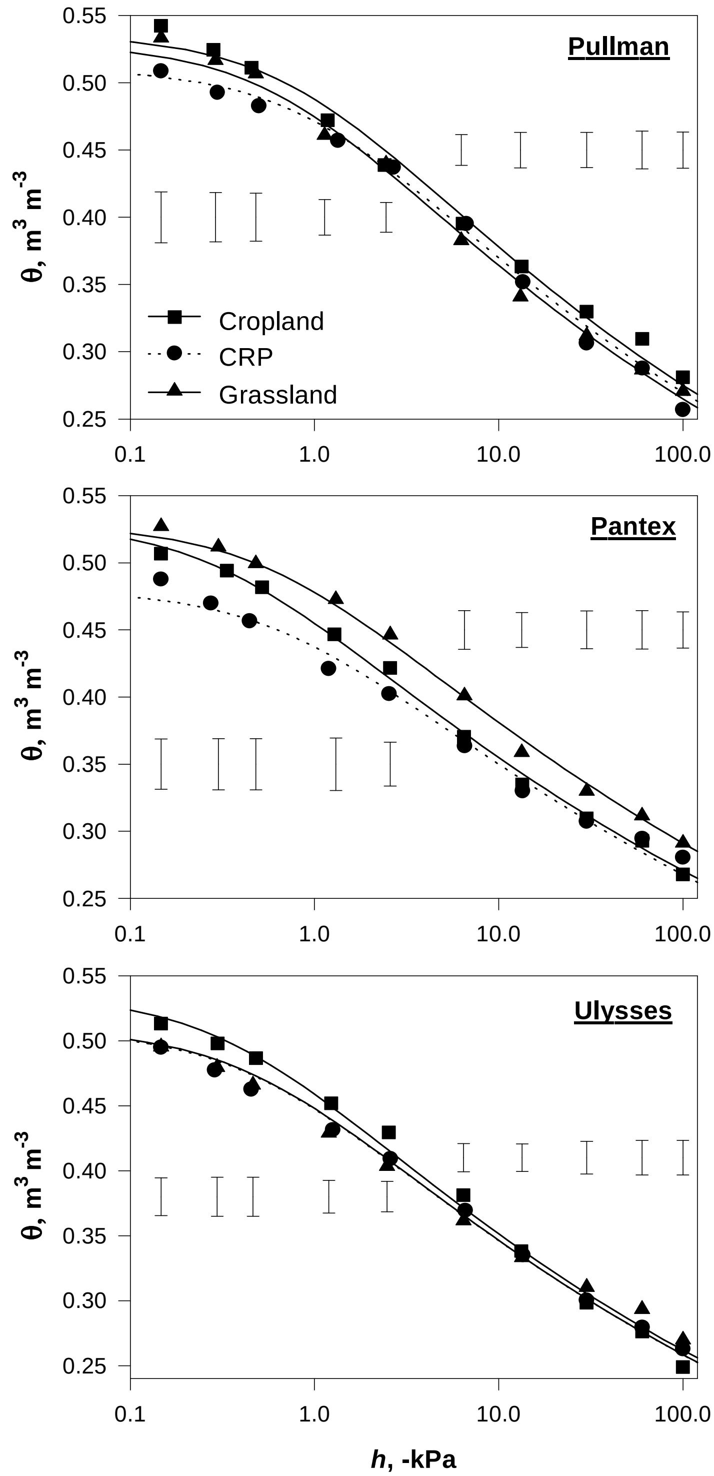

Fig. 1. Soil water retention curves for the Pullman, Pantex, and Ulysses soils for the combined 0.01 to 0.04 and 0.05 to 0.08 -m depth increments. Lines are least-square fits to Eq. (1). Error bars are least significant differences across all plots at each location for a particular pressure head.

Table 3
Fitted parameter values and 95% confidence levels obtained from the fit of Eq. (1) to $\theta(h)$ data from the 0.01 to 0.04 and 0.05 to 0.08 -m depth increments. Saturated water content θ_s was estimated from plot averages of bulk density and n was fixed at the mean obtained for each location.

Land use	Parameter Estimates [a]					
	n [b]		θ_s		α	
	-		($m^3\ m^{-3}$)		(m^{-1})	
			Pullman			
Cropland			0.536	± 0.019	10.91	± 1.13
CRP	1.143	± 0.019	0.510	± 0.018	8.93	± 1.31
Grassland			0.529	± 0.006	13.12	± 2.04
			Pantex			
Cropland			0.530	± 0.010	27.42	± 4.18
CRP	1.121	± 0.022	0.480	± 0.008	13.17	± 1.85
Grassland			0.528	± 0.008	14.40	± 2.33
			Ulysses			
Cropland			0.535	± 0.016	24.53	± 3.00
CRP	1.131	± 0.026	0.508	± 0.016	18.33	± 2.45
Grassland			0.509	± 0.010	18.52	± 2.26

[a] Mean ± 95% confidence level.
[b] Fixed the value of n by location to the mean value.

3.3 Hydraulic conductivity

Land use was the major factor responsible for explained variability in $K(h)$ across locations, especially at the largest supply pressure head. At supply pressure heads less than –50 mm, grassland and CRP land conductivities were similar across all locations (Fig. 3). Near saturation,

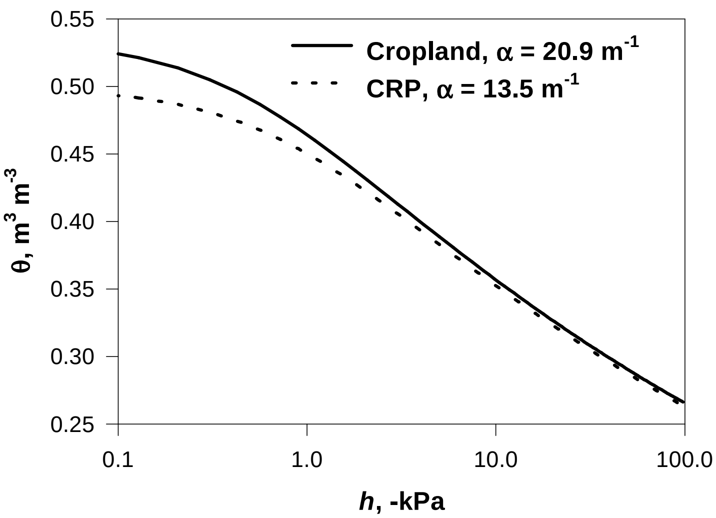

Fig. 2. Fitted water retention functions averaged among all three soils for cropland and CRP land and the corresponding fitted values of α typifying reconsolidation effects.

$K(h = -5$ mm) of grassland plots exceeded conductivities of CRP plots. Large near-saturated conductivities on grassland are most apparent on the Pullman soil, likely because of the absence of heavy grazing (such as occurred at the Pantex and Ulysses sites) that can obstruct surface pores and increase compaction. The hydraulic conductivity of sweep-tillage cropland exceeded ($P < 0.05$, $df = 18$) conductivities of grassland and CRP sites at supply pressure heads less than –50 mm on the Pullman and Pantex soils and at all potentials on the Ulysses soils (Fig. 3). Higher conductivities for the Ulysses cropland soils may have resulted from the occurrence of free carbonates at the surface that would promote aggregate stabilization. Ignoring minor location effects, Table 4 provides a reflection of the overall trend in measured conductivities as influenced by land use averaged across all locations.

Hydraulic conductivities of no-tillage cropland for the Pullman soil (Fig. 3) compared closely with those of CRP land across the entire range in supply pressure heads. Hydraulic conductivities for sweep-tilled cropland on the Pullman soil were greater than on no-tillage plots throughout the entire measured range (Fig. 3). Kribaa et al. (2001) recorded similar responses in comparing unsaturated conductivities under disc-tillage and no-tillage fallow for a silty-clay soil. Although sweep-tilled cropland has an initially higher saturated conductivity, Jones et al. (1994) reported that steady state infiltration rates were similar between sweep-tillage and no-tillage on a Pullman soil after reconsolidation and crusting of the tilled surface. Cropland used in this study was only recently (≤ eight weeks) tilled prior to infiltration measurements and there was only a small amount (< 50 mm) of intervening precipitation, thereby minimizing aggregate disintegration and slowing the rate of reconsolidation. Nonetheless, reconsolidation would have tended to mask differences between cropland and other land uses. At the largest water potential for the Pullman soil, $K(h = -150$ mm) was 3.0 and 1.4 times greater with sweep-tillage compared with no-tillage cropland and CRP land, respectively. Typically, studies have indicated greater conductivities at $h \lesssim -100$ mm for tillage as compared with no-tillage for fine-textured soils (Ankeny et al.,1990; Benjamin, 1993; Logsdon et al., 1993; Wu et al., 1992; Evett et al., 1999; Kribaa et al., 2001), although significant differences have usually not been detected at these larger water potentials for which conductivity is small.

3.4 Pore structure, conductivity, and land use

The pore size density function for the potential range of approximately –0.15 to –3.0 kPa for Pantex and Ulysses soils (Fig. 4) exhibits minor but important differences among land use treatments. Greater pore volumes throughout the larger pore radii for the cropland, resulting from the loosening effect of tillage, corresponded with increased near-saturated hydraulic conductivity (Fig 3). Similar pore volumes between CRP and grassland for the Ulysses soil, yet higher conductivities for grassland, suggest that shrink-swell cycles and/or biological activity has given rise to development of less tortuous and more continuous pores under native grassland as compared with the recently established CRP land. Moreover, the $K(h)$ relationships for grasslands and CRP land suggest these long-term effects on grasslands were confined to large pore sizes (e.g. > 300 μm). Lastly, the pore size density functions converge as the pore sizes decrease, indicating that both tillage and biologically mediated pore formation primarily affected the large pore size classes.

Experimental evidence (Hadas, 1997) and a pore size evolution model (Or et al., 2000) indicate that, although saturated conductivities of aggregated beds simulating tilled soils are

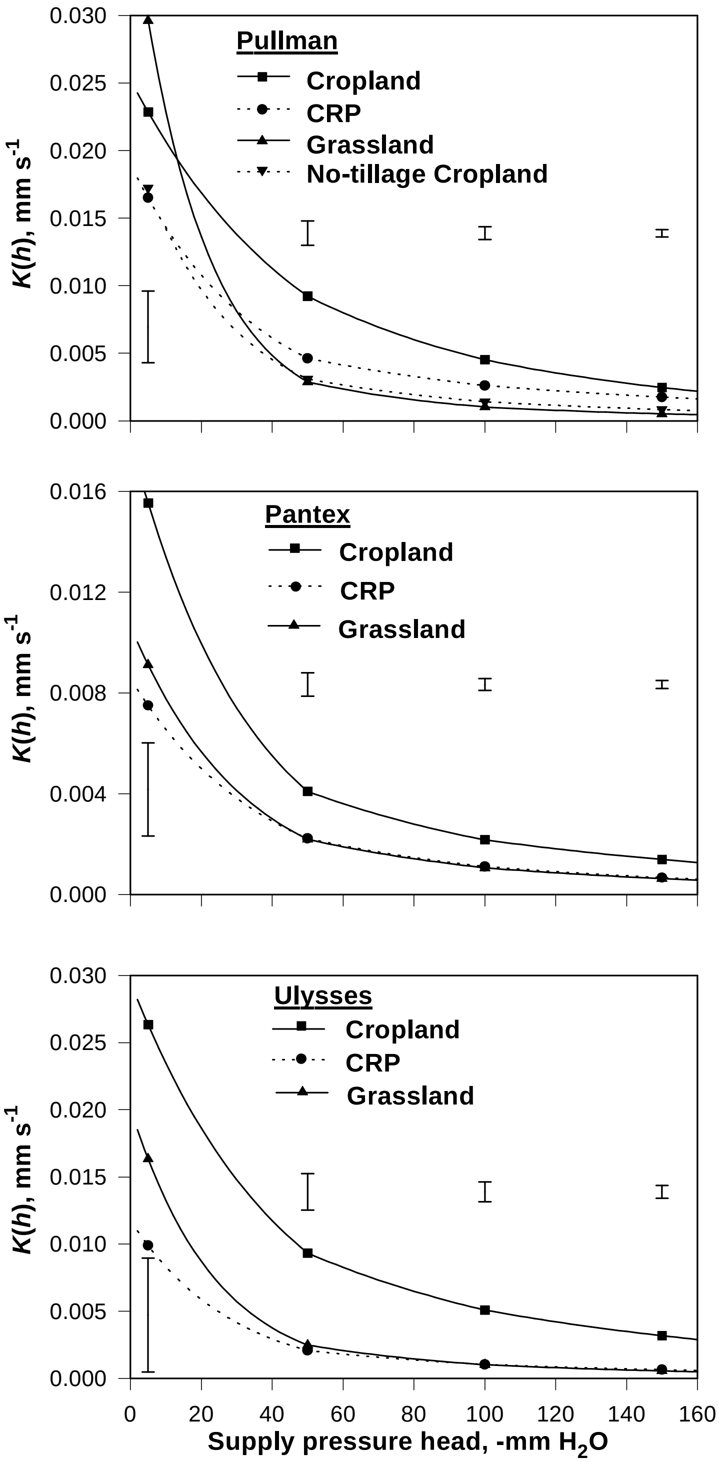

Fig. 3. The observed mean $K(h)$ relationship for the Pullman, Pantex, and Ulysses soils. Lines are piecewise-loglinear interpolations. Error bars are least significant differences across all plots at each location for a particular supply tension.

Table 4
Mean values of unsaturated hydraulic conductivities by land use.

Land Use	$K(-5)$[a] ($10^3 \cdot$ mm s^{-1})	$K(-50)$ ($10^3 \cdot$ mm s^{-1})	$K(-100)$ ($10^3 \cdot$ mm s^{-1})	$K(-150)$ ($10^3 \cdot$ mm s^{-1})
Cropland	21.6 a	7.56 a	3.92 a	2.34 a
CRP	11.3 b	2.97 b	1.58 b	1.02 b
Grassland	18.4 a	2.52 b	1.03 b	0.567 b

Mean values in the same column with different letters are significantly ($P < 0.05$) different using Fishers protected LSD test.
[a] $K(h)$ where h is in units of mm H_2O.

larger than their consolidated counterparts, at larger potentials this trend reverses such that consolidated beds have the highest unsaturated conductivity. The post tillage pore space evolution model of Or et al. (2000) shows that conductivities of aggregated beds intersect with conductivities of their consolidated counterparts at approximately –2 kPa for a particular scenario. In this study, substitution of the average fitted α and estimated K_s into the VGM conductivity function for each land use likewise suggests that unsaturated conductivities of native grassland and CRP land should be larger than those for cropland at the lowest supply pressure head. In contrast, unsaturated conductivities of cropland at $h = -150$ mm were 2.3 to 4 times greater than conductivities of CRP land, no-tillage cropland, and native grasslands, all of which represent consolidated states. Thus, these conductivity functions, which were derived from

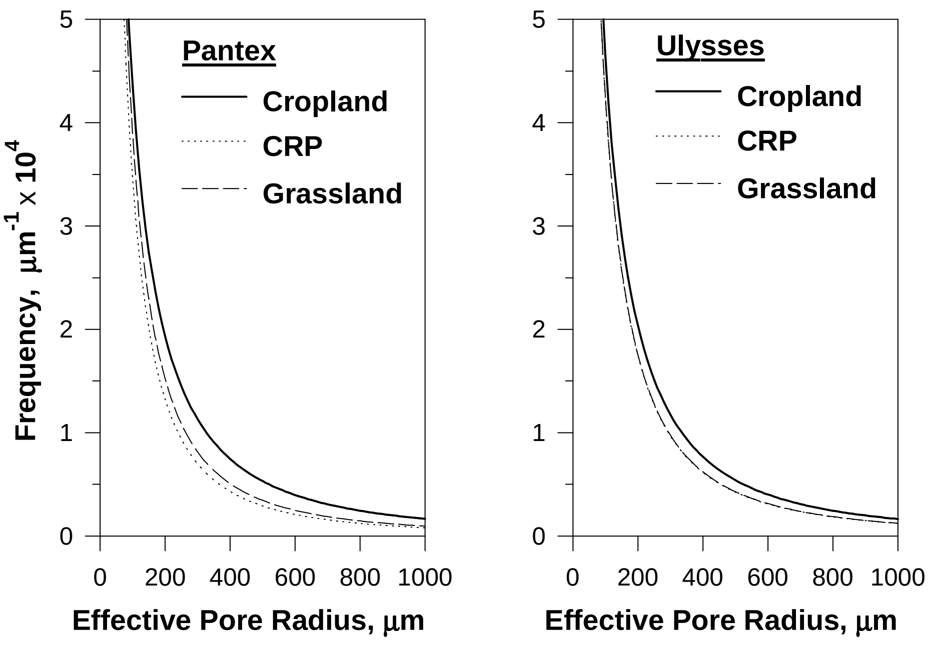

Fig. 4. Effective pore-size density for the larger pore radii classes calculated using the water characteristic curves of Pantex and Ulysses soils for the 0.01 to 0.04 and 0.05 to 0.08 -m depth increments.

assumptions about random arrangement of interconnected pores, may satisfactorily represent consolidation effects but do not properly account for other processes that influence pore connectivity. Long-term pore evolution after tillage in these soil results from two competing processes: (i) reconsolidation that effects a shift in the pore size distribution towards smaller pores and (ii) the development of stable macropores via rooting activity and wetting-drying cycles. Macropore development in soils can decrease the frequency of pores in the smaller size classes thereby potentially decreasing the unsaturated conductivities. Shrinkage cracks may also cause a reduction in unsaturated conductivities because of the presence of a continuous air interface. Such mechanisms were likely responsible for the low unsaturated conductivity of grasslands at the largest potential (h = –150 mm) in comparison with cropland. The CRP land had intermediate unsaturated conductivities at this potential because macropore development, as indicated by low near-saturated hydraulic conductivities, had only partially compensated for reconsolidation effects. For the fine-textured soils in this study, a reduction in unsaturated conductivity, which would tend to reduce bare soil evaporation rates, would be an important consideration in comparing precipitation use efficiencies of dryland management alternatives.

The degree of soil structure development via shrink-swell cycles or biological activity on CRP land has yet to achieve the level of macroporosity characteristic of grasslands that contributed to greater near-saturated conductivities. Similar conductivities between CRP and no-tillage plots for the Pullman soil likewise suggest that perennial grasses had little impact on modifying soil hydraulic properties over the ten years since the land use was converted from cropland to grassland. In a comparison of CRP land, cropland, and native grassland at 11 locations in the southern high plains of Texas, Unger (2001) concluded that increases in organic matter and aggregate stability after establishment of grass perennials on CRP land would take considerably longer than 10 years to approach levels on native grasslands. In contrast to other studies (e.g. Weinhold and Tanaka, 2000), our results indicate that for this semi-arid climate the rate of soil structural development related to hydraulic properties is relatively slow.

4. Conclusions

Land use practices had a greater effect on water movement in soils than did soil type. As such, the parameterization of soil hydraulic properties based solely on soil type may lead to inaccurate predictions of infiltration and redistribution and poor comparative assessments of precipitation use efficiency among management alternatives. Conservation Reserve Program sites had significantly lower near-saturated conductivities (h = – 5 mm) than native grassland counterparts. Apparently, the degree of macropore development on CRP sites required to obtain the high saturated conductivities characteristic of native grasslands would take considerably longer than ten years.

Reconsolidated CRP grasslands examined in this study had larger bulk densities and smaller water retention at small potentials (h > –10 kPa) than recently tilled cropland. Soil settling and consolidation effects on the van Genuchten retention function for the fine-textured soils used in this study could be modeled using a smaller value of α in conjunction with a smaller saturated water content. Although process oriented models (e.g., Or et al., 2000) can satisfactorily describe short-term pore dynamics due to reconsolidation after tillage, more generalized models that include the effects of stable macro-pores originating from rooting activity and wetting-drying cycles will likely be required to better describe the many subtleties of pore evolution and resultant changes in hydraulic conductivities over the long-term. Adaptation of such models for fine-textured soils presents a considerable challenge.

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